
Magnetism

Introduction

This topic explores the key concepts of magnetism as they relate to:

- the phenomenon of magnetism
- magnetic forces and fields
- a theory of magnetism.

Key concepts of magnetism

The activities in this topic are designed to explore the following key concepts:

- Magnets exert a force that can be described as a ‘push’ or a ‘pull’.
- Magnets exert a force field that is called a ‘magnetic field’. A magnetic field is a region in space around a magnet that will exert force on another magnet or magnetic material.
- Magnets attract materials composed of iron and nickel; these materials are described as being magnetic.
- Magnets vary in strength, size and shape.
- Magnets have north and south poles. The attracting power (magnetic field) of a magnet is greatest at its poles.
- Like poles of a magnet attract; unlike poles repel.
- Atoms are tiny constituents of matter and act like tiny magnets. In magnets and magnetic materials atoms form groups called ‘domains’, where their magnetic poles are aligned.
- In magnets, domains align themselves (north poles are in the same directions). In non-magnetic materials domains do not align themselves magnetically.
- Magnetic materials are made into temporary magnets by bringing them near a permanent magnet.
- Earth can be considered to be one large magnet.
- Temporary magnets can be made from a nail, wire and battery because an electric current produces magnetism.

Students' alternative conceptions of magnetism

Research into students' ideas about this topic has identified the following non-scientific conceptions:

- Poles are only at the ends of magnets.
- Big magnets are stronger than small magnets.
- Larger magnets are stronger than smaller magnets.
- The magnetic and geographic poles of Earth are located at the same place.
- The geographic and magnetic poles of Earth are identical.

The phenomenon of magnetism

Playing with magnets provides a source of interest for young and old alike. Students will have some knowledge of magnets, as magnets are common in everyday life, but they often expect magnets to attract any metal object rather than only iron and steel. Magnets have no effect on aluminium, brass, silver or copper. A difficulty for students in exploring this is that they will not know from what metal common objects are made, and some substances that look like metal are in fact plastic-coated. Also, some plastic-coated objects, such as paperclips, have metal within them.

To understand magnetism we need to refer to our representations or models of the molecular and atomic world. We also need to make connections with the phenomena of electricity—they are very much linked. For example, consider an electric generator and electric motor. Each has two main components: a coil of wire and a magnet. In the generator the wire is moved with respect to the magnet; this makes electrons move in the wire and electricity is created. In the motor, electrons are moved in the coil by connecting it to a battery; this moves the coil of wire, spinning it.

Magnetism is a phenomenon created by moving electric charges. As electrons and protons have the smallest electric charge, and because these particles are always in constant motion (whether moving around or spinning), each of these particles can be considered to be a small magnet. As previously mentioned, all matter contains atoms that are composed of electrons and protons. Within the atom the magnetic effect of the electrons does not cancel out the magnetic effect of the protons and so the atom may be considered to be a tiny magnet. Therefore, as all matter is composed of atoms, all matter is both electric as well as magnetic. This begs the question 'why don't all objects exhibit electric and magnetic effects?'. The topic 'Electricity' explains that all objects do not show electrical effects because in most objects the effects of the electric charge on the protons cancel out the effects of the electric charge on the electrons. A similar effect occurs in explaining why all objects do not show magnetic effects.

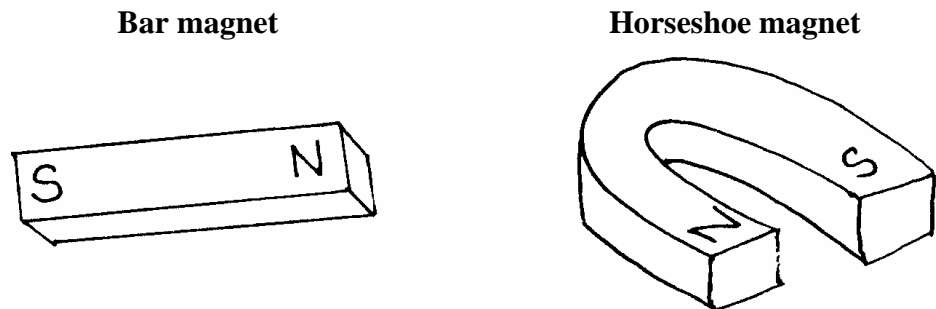
Magnetic forces and fields

Magnets exert a force on other magnets—and some metals—that can be described as a ‘push’ or a ‘pull’. As these forces act over a distance (for example, a magnet can attract a paperclip even over a distance of some centimetres), scientists describe the magnet as exerting a magnetic field. The magnetic field is a force field that can be described as a region around the magnet that will attract/repel other magnets and some metals. Magnetic fields are therefore like electric fields and gravitational fields.

Magnets attract materials composed of iron and nickel; these materials are described as being ‘magnetic’. There is a common view among students that magnets attract all metals. This is not true; magnets will not attract metals such as aluminium, copper, gold, silver and lead. A metallic object that contains some iron or nickel will be attracted to a magnet.

The attracting power of a magnet occurs at its ends. These ends are called poles: north pole and south pole (see Figure 1). If you suspend a magnet by a thread you should notice that it will align itself with Earth’s magnetic field so that the north pole of the magnet points to Earth’s geographical North Pole and the south pole of the magnet will point to Earth’s geographical South Pole. This is what a compass does; a compass is just a magnet that is balanced so it can rotate horizontally.

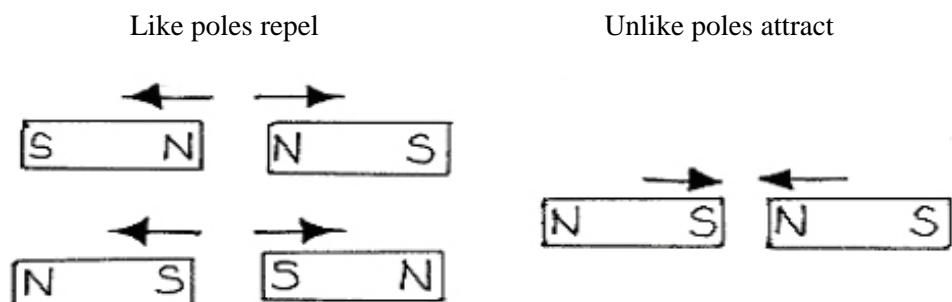
FIGURE 1:
MAGNETS HAVE
NORTH AND SOUTH
POLES



Magnets can vary in strength, size and shape. The most common types are bar magnets, discs and horseshoe magnets, although many new fridge magnets are flat strips. All of these magnets have poles at either end.

Two magnets interact with each other so that ‘like poles repel’ and ‘unlike poles attract’ (see Figure 2).

FIGURE 2:
FORCES BETWEEN
MAGNETS

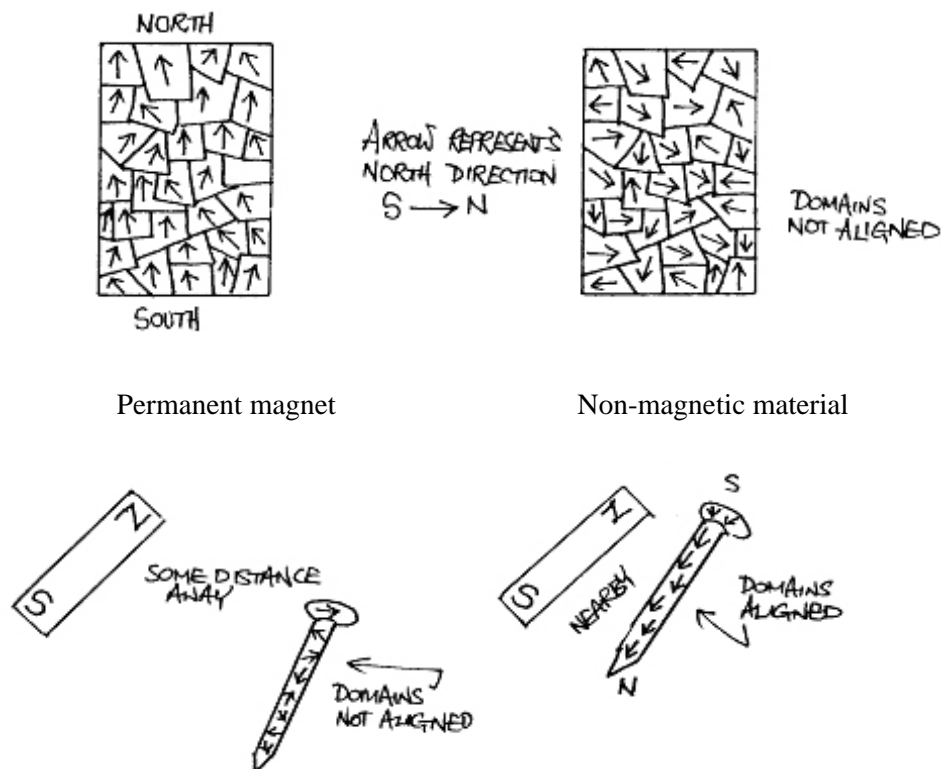


A theory of magnetism

To understand the properties of magnets described earlier in this topic we need to understand what is happening on a microscopic scale. As mentioned earlier, all atoms can be considered to be tiny magnets. Therefore each atom has a north pole and a south pole. The power of these tiny magnets is extremely small, but magnetic power (size of the magnetic field) can increase if the atoms align themselves so that their north poles point in the same directions. In permanent magnets many of the atoms have aligned themselves; the greater the alignment the stronger the magnet. You may notice from this description an explanation for the observation that if you cut a magnet in half you will obtain two magnets. Further cutting creates more magnets.

Most materials do not act like magnets as their atoms are not aligned in terms of magnetic poles. In magnets and other magnetic materials the atoms arrange themselves into groups, called ‘domains’. The atoms in each domain have their magnetic poles aligned. In a magnet many of these domains are aligned, but in a piece of iron these domains are not aligned. However, if one brings a magnet near a piece of iron, such as a nail, the domains in the nail will become aligned. This has the effect of turning the nail into a temporary magnet and so it will be attracted to the permanent magnet (see Figure 3).

FIGURE 3:
MAGNET
ATTRACTING
AN IRON NAIL



Damaging magnets and making new magnets

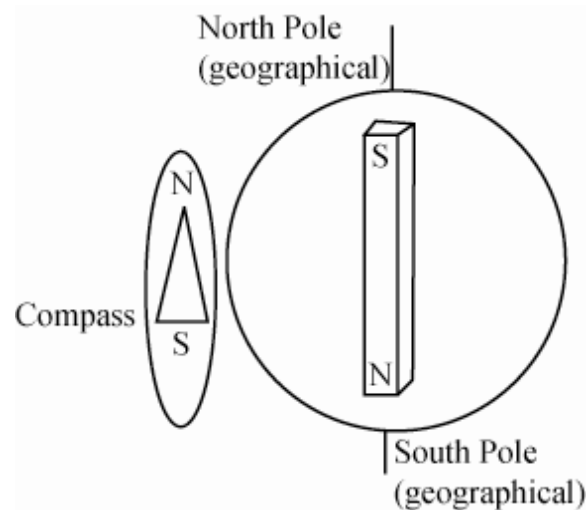
Permanent magnets have domains with permanently aligned poles. However, by heating or dropping magnets the domains may be knocked out of alignment, causing the magnet to lose its magnetic ability. Magnets must therefore not be handled roughly. A magnetic material like an iron nail can be made into a permanent magnet by placing it in the magnetic field of a permanent magnet over an extended period of time. This can also be achieved by continually rubbing a pole of a permanent magnet down the side of the nail, ensuring that you always rub in the same direction.

Temporary magnets can be made from an iron nail, long piece of wire and a battery. After winding the wire around the nail many times, connect it to a battery. This will cause electrons to run down the wire (electric current), causing a magnetic field in the iron nail. The result is a temporary magnet called an ‘electromagnet’. By disconnecting the wire the magnetic power of the nail ceases.

Compasses and Earth’s magnetic field

As mentioned earlier in this topic, compasses are just freely moving magnets. Permanent magnets may be used as magnets if you allow them to swing freely in a horizontal plane. Magnets point north because Earth may be considered to be a huge magnet. Scientists believe that Earth’s iron core and currents of liquid rock give rise to this magnetism. In Figure 4 Earth can be viewed as having a permanent magnet inside it. The north pole of this permanent magnet is located at the geographical South Pole of Earth. The south pole of the permanent magnet is located at the geographical North Pole of Earth. This can be somewhat confusing, but it explains why a magnet’s north pole points to geographical north—because unlike poles of magnets attract one another.

FIGURE 4:
EARTH AS A
MAGNET



Activities

ACTIVITY: INTRODUCING MAGNETS

Introduce a number of magnetic gadgets to the students and get them to tell you what they know about them.

You may like to ask them:

- What are magnets used for?
- Where can magnets be found?
- What are magnets attracted to?

ACTIVITY: THINGS THAT ARE ATTRACTED TO A MAGNET

You will need:

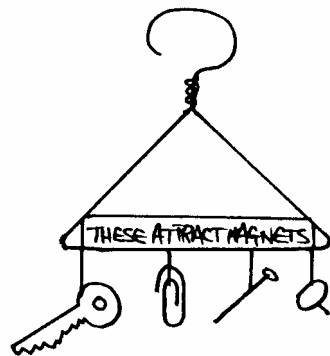
- a bar magnet
- a record sheet
- two wire coathangers
- some fishing line.

Ask the students to move around the classroom quietly, selecting objects to test with their magnet. Get them to name and describe the objects on their record sheet. The activity should continue as a predict–observe–explain (POE) task, where the students undergo three stages:

- 1) students predict if the object ‘sticks’ to the magnet (record this on their record sheet)
- 2) students test the object and record their observations
- 3) students write down conclusions about what things are attracted to a magnet.

The students can then make a mobile of things that are attracted to magnets and another one of things that are not attracted to magnets (see the figure *Mobile of magnetic materials*).

FIGURE:
MOBILE OF
MAGNETIC
MATERIALS



ACTIVITY: INTERACTIONS BETWEEN MAGNETS

You will need:

- two bar magnets
- a horseshoe magnet
- watch glasses (optional).

Arrange the magnets so that the north ends are facing each other. Slowly bring them closer together. What happens? Do they attract or repel one another?

Now try putting the south ends together. What if the north and south ends are facing each other? What happens if a horseshoe magnet and a bar magnet are used?

If you have watch glasses you can place a bar magnet across one of these and the magnetic interactions will be even more interesting.

Make up a chart to go on the wall, showing the arrangements of magnets and a sentence to tell what happens in each case.

ACTIVITY: THE
STRENGTH OF
MAGNETS

You will need:

- a collection of different magnets
- iron filings
- plastic wrap
- paperclips.

When using iron filings with magnets it is best to first cover the magnets with plastic wrap. Otherwise, you will find it difficult to remove the filings from the magnets at the completion of the activity.

Students test the strength of the various magnets. Cover each magnet with iron filings. Where on the magnet does it attract best? Does the north pole attract just as well as the south pole?

Test the strength of each magnet by determining how many paperclips each can pick up.

ACTIVITY:
EXTENDING
THE REACH OF
A MAGNET

You will need:

- a strong magnet
- paperclips
- a large nail.

Hold a nail against one pole of a strong magnet. The nail is itself magnetised while it is in contact with the magnet and can pick up paperclips or other objects.

Check whether the nail retains its magnetism when it is no longer in contact with the magnet.

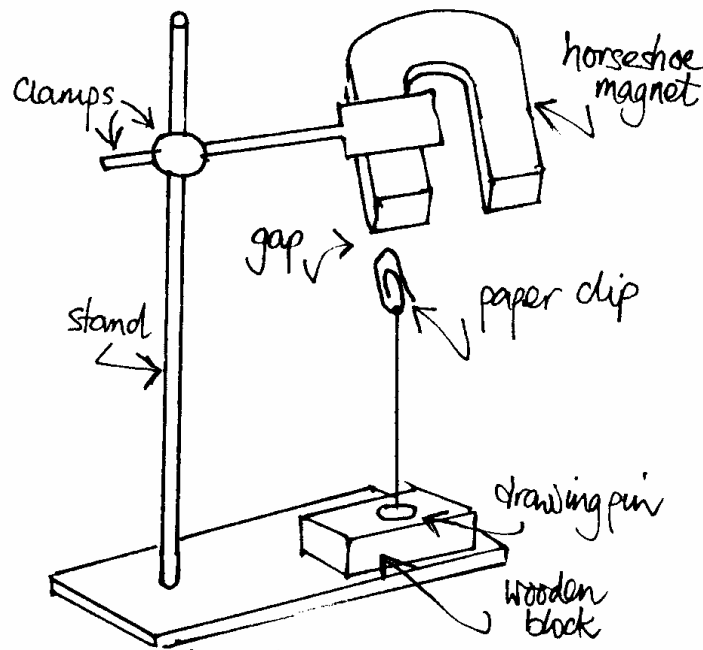
ACTIVITY:
MATERIALS
THROUGH
WHICH A
MAGNETIC
FIELD WILL
PASS

You will need:

- a horseshoe magnet
- thin sheets of various materials
- paperclip
- cotton
- a small block of wood
- a drawing pin
- a retort stand and clamps.

Set up the equipment as shown in the figure below.

Select a sheet of some material. Predict whether the magnetic field will pass through the material. Test your prediction by passing the material through the gap between the magnet and the paperclip. If the paperclip does not fall then the magnetic field has passed through the material.



ACTIVITY:
MAGNETS AND
COMPASSES

Investigate what happens when a magnet or piece of iron is brought near a magnet compass. Why is the case of the compass made of brass or aluminium?

ACTIVITY:
HOW MANY
MAGNETS?

Observe the variety of magnets found around the house/school. Can you see a pattern?

ACTIVITY:
MAKING
MAGNETS

You will need:

- large nails
- a bar magnet
- paperclips (or pins)
- insulated copper wire
- a battery
- a darning needle
- a polystyrene cube
- a shallow dish of water.

Method 1

Stroke a nail with a magnet, in one direction only. Test how many paperclips you can pick up after ten strokes, twenty strokes and thirty strokes. Record your findings. Hit the nail with a hammer a few times. Test it with the paperclips again. What happened? Why?

Method 2

Wind some insulated wire around a nail, leaving about 10 cm of wire at each end. Attach the bare ends of the wire to the terminals on the battery. After a minute or two test the nail to see if it will pick up paperclips. You have made an electromagnet. Test to see if the number of coils around the nail makes any difference to the strength of the magnet.

ACTIVITY:
MAKE A
TEMPORARY
COMPASS

Stroke a darning needle until it is magnetised. Push the needle through a cube of foam and float it in a saucer of water. It should point north–south (note: keep it away from magnets!).

ACTIVITY:
MAPPING
MAGNETIC
FIELDS

You will need:

- a sheet of cardboard (for example, cover paper)
- a shaker of iron filings
- two bar magnets
- a horseshoe magnet
- a funnel
- spray paint
- newspaper
- turpentine.

Arrange the magnets and place the cardboard on top of the magnets. Carefully sprinkle the iron filings onto the cardboard until a clear pattern of lines can be seen. Draw the pattern you see.

Return the filings to the shaker using the funnel. Now try different arrangements of the magnets. Draw the patterns you see.

Another way to record this activity is to select a favourite pattern. Lay out the newspaper on the floor, set up the arrangement and sprinkle it with iron filings. Spray paint onto the arrangement. After about 10 minutes, brush the filings onto another piece of card and then soak them in turpentine to remove the paint. Later you can dry them on paper towel and tip them back into the shaker.